THE EVERGLADES MERCURY TMDL PILOT STUDY: FINAL REPORT

A MODELING ANALYIS of MERCURY EMISSIONS, TRANSPORT and DEPOSITION, and AQUATIC CYCLING and BIOACCUMULATION in the FLORIDA EVERGLADES
Florida Department of Environmental Protection, 2003

In 1999 Florida DEP and USEPA began a modeling analysis of the environmental cycle of mercury to explore the tools and data needed to perform a Total Maximum Daily Load analysis (TMDL) for an atmospherically derived pollutant. Mercury is a persistent, toxic pollutant largely of anthropogenic origin. Gaseous and particulate forms cycle through air, water, soils and sediments, strongly biomagnify in aquatic food webs, and thereby pose risk to humans and wildlife. Extensive Everglades-specific data are available to support a linked, multi-media modeling analysis through the auspices of the South Florida Mercury Science Program (see reverse), a 10-year multi-agency program of research, modeling and monitoring studies.

Methods:

1. Meteorology — Long-term variability in monthly and annual Hg deposition rates due to climatic variation (and measurement uncertainty) on Hg concentrations in largemouth bass was simulated by analyzing variations in monthly wet deposition at three Florida Atmospheric Mercury Study sites (FAMS) observed between 1993 and 1997. The character and magnitude of these variations were used to synthesize a 500-year dataset that then was as input to the E-MCM model.
2. Transport and Fate — The effect of local emissions on wet and dry deposition fluxes of Hg in the Everglades were simulated based on metrological inputs derived for south Florida from the RAMS model (*U. Co.)* and transport and deposition dynamics simulated using the HYSPLIT model (*NOAA*) by the University of Michigan Air Quality Lab.
3. Deposition — Measured mercury deposition by FAMS (*FSU*), which compared well with modeled, was used as deposition input to aquatic cycling in Everglades marshes.
4. Modeling — The Everglades Mercury Cycling Model (E-MCM, *Tetra Tech*) received input from atmospheric deposition, then simulated the physical, chemical and biological processes that control methylmercury production and bioaccumulation to fish of various trophic levels.
5. Synthesis — Linkage of monitoring and research data with these modeling approaches has resulted in a demonstration of the utility of an air-water/sediment-biota approach to quantifying the relationships between the multiple media representing the problem of mercury in fresh water ecosystems.

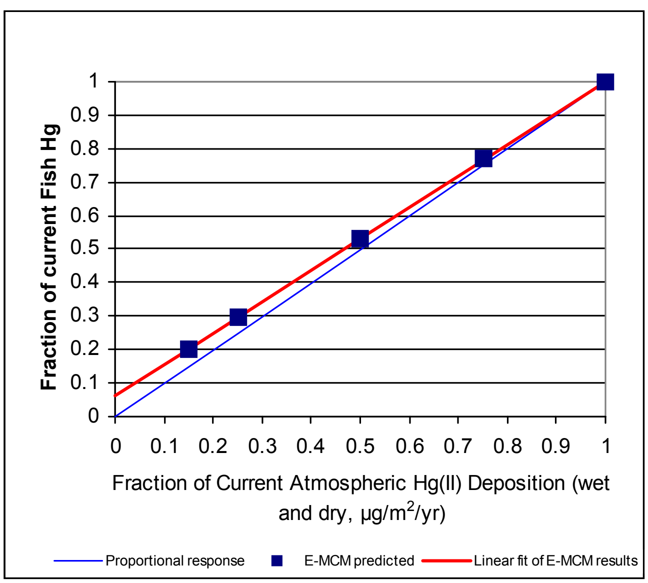

Figure 1. Modeled response of Everglades system to changes in mercury load. A linear response is predicted, with a slight departure from 1:1 because of some remobilization of mercury from deeper sediment layers.

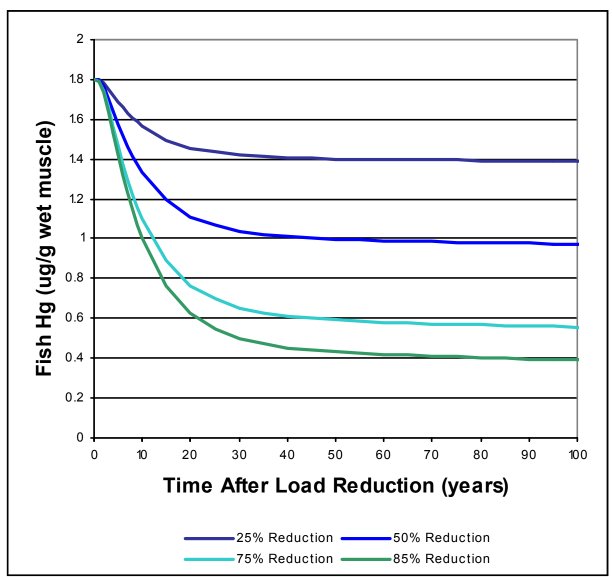

Figure 2. Response of 3-yr-old largemouth bass to changes in mercury load. Response time is independent of change in load. Fish mercury response is approximately half that of load reduction in ca. 10 yr., and nears equilibrium in ca. 30 yr.

Key Findings:

1. The E-MCM predicts a linear relationship between atmospheric mercury deposition and mercury concentrations in largemouth bass, with a small residual mercury concentration in fish at zero atmospheric mercury deposition: for any reduction in mercury inputs to the Everglades a slightly lesser reduction in fish mercury concentrations may be anticipated. Furthermore, the E-MCM predicts near equivalence between the change in atmospheric mercury deposition rate and the change in largemouth bass mercury concentration over the likely range for current estimates of atmospheric deposition of mercury. The slight offset from a 1:1 relationship (Figure 1) results from slow mobilization of historically deposited mercury from deeper sediment layers to the water column. Until buried below the active zone, this mercury can continue to cycle through the system. In addition, because mercury is a naturally occurring element, fish tissue mercury concentrations can never be reduced to zero.

2. Absent changes to the system other than mercury loading (e.g. sulfur or nutrient cycling, or hydrology), an ~80% reduction from the ca. 1996 peak total annual mercury atmospheric deposition would be needed for mercury concentrations in a 3-year old largemouth bass in the central Everglades to be reduced to less than Florida's present fish consumption advisory action level of 0.5 mg/kg.

3. With sustained mercury load reductions, mercury in three-year-old largemouth bass is predicted to achieve 50% of its long-term, steady state response within ca. 10 yr. and 90% within 30 yr (Figure 2).

4. Despite the uncertainties identified, the progress represented in these demonstrations of a unique combination of atmospheric and aquatic cycling models is remarkable. There is reason to believe that, with modest additional effort, the remaining uncertainties can be reduced to levels that will allow reliable, confident allocation of mercury emissions to protect the designated uses of the Everglades.

5. It is evident that there is further potential for combining such air and water modeling approaches for TMDLs involving air deposition of mercury for other aquatic ecosystems. We believe the approaches presented here can be applied to other geographic areas and in other studies of air – water chemical interactions.

Present Situation: Incinerator mercury emissions in southern Florida have declined approximately 99% since the mid-1980's as a result of pollution prevention and control policies. In general accord with Figure 2, mercury in fish and wildlife of the Everglades has declined by approximately 60% since the mercury peaked in biota in the mid-1990's.

Unique factors in this analysis:

This analysis should be extrapolated to other waters with caution because of unusual attributes of the Everglades:

- Physiography of the waterbody — As a flat, shallow, vegetated marshland the Everglades is atypically vulnerable to atmospheric deposition because of its great surface-to-volume ratio.
- Climate — Year-round high temperature and insolation stimulates chemical and physical processes, promoting rapid aquatic cycling and unusually high production of methylmercury.
- Meteorology — Easterly trade winds typify the synoptic transport regime during the summer when ~ 85% of rainfall and ~ 90% of mercury deposition occurs. This pattern efficiently brings emissions from the southeast coastal counties of Florida out over the Everglades where frequent thunderstorms focus deposition there.
- Sources — Incineration was the largest emissions category in south Florida through the mid-1990's. A predominance of emissions was 'reactive gas-phase mercury' {RGM or Hg(II)} which tends to deposit on a local scale.
- Synergy — Coupled with meteorology described above, the dominance of emissions as RGM has resulted in an unusually tight local-scale coupling between emissions in southern Florida and local-scale deposition.

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Additional information at: http://www.floridadep.org/labs/mercury/index.htm

South Florida Mercury Science Program Participants: